AUSTRALIA
NEW ZEALAND

EXERCISE PHYSIOLOGY

SCOTT K. POWERS & EDWARD T. HOWLEY

EXERCISE PHYSIOLOGY

AUSTRALIA | NEW ZEALAND

Dedication

Anthony Leicht: To my loving wife Annette, for her everlasting support and love; to my girls Maddison and Samantha, who brighten up my life every day; to my mother Kay, and grandparents Noel and Jean, for their endless love and guidance to succeed; and to Graham Allen for his passion for exercise physiology and his long-lasting friendship.

Jim Cotter: To Kate, Hamish, Charlotte, Lucy and Grace.

Kate Pumpa: To my husband Rhys, mother Susan, father Geoff and sisters Lisa and Holly.

EXERCISE PHYSIOLOGY

AUSTRALIA | NEW ZEALAND

Scott K. Powers
University of Florida

Edward T. Howley
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Contents in Brief

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Appendices can be accessed at www.mhhe.com/au/powers1e

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Appendices can be accessed at www.mhhe.com/au/powers1e

Preface

Exercise Physiology: Australia and New Zealand is intended for students interested in exercise physiology, clinical exercise physiology, human performance, kinesiology, sports and exercise science, physical therapy and physical education. The overall objective of this text is to provide the student with an up-to-date understanding of the physiology of exercise.

This text contains numerous clinical applications, including exercise tests to evaluate cardiorespiratory fitness and information on exercise training for improvements in health-related physical fitness and sports performance.

Continuing the legacy of the American editions of this text, the central theme of the book remains the regulation of homeostasis during exercise. However *Exercise Physiology: Australia and New Zealand* builds on the foundation of the original text and provides context for students studying in Australia and New Zealand and academics teaching courses in these countries.

While the core concepts of exercise physiology remain constant across the world, this local edition has allowed us to make the text more relevant and engaging for students studying in Australia and New Zealand. From making examples more applicable by reflecting sports that are played here, to considering both the historically rich and current research produced in both countries, and by including local statistics, guidelines and units of measurement, we hope that this edition of the text will be the best resource for students studying exercise physiology in Australia and New Zealand.

Acknowledgments

Teamwork has been an essential part of the creation of this important book. We are very proud to acknowledge the contributions made by our esteemed author team; without their experience and passion this text would not have been possible.

- **Jim Cotter**: I am grateful to my colleagues and postgraduate students who willingly share their perspectives and knowledge.
- **Kate Pumpa**: Dr Ben Rattray for the time you take to edit, answer questions and discuss my teaching and research ideas, and Ms Disa Smee for your continual support and friendship.

Reviewers

We owe special thanks to the many distinguished colleagues and peers who provided research and review feedback as we prepared this Australian and New Zealand edition. Many of the improvements in this book are the result of their comments. In this regard, we sincerely appreciate the time and effort contributed by the following academics:

- Ajmol Ali, Massey University
- Stephen Bird, Charles Sturt University
- Kate Edwards, University of Sydney
- Trevor Farr, Victoria University
- James Fell, University of Tasmania
- Deborah Fletcher, AUT University
- Guy Gregory Haff, Edith Cowan University
- David Jenkins, University of Queensland
- Nathan Johnson, University of Sydney
- Justin Kavanagh, Griffith University
- Danielle Lambrick, Massey University
- Justen O'Connor, Monash University
- Jeremiah Peiffer, Murdoch University
- Kieron Rooney, University of Sydney
- Michael Simmonds, Griffith University
- Wade Sinclair, James Cook University
- Karen Wallman, University of Western Australia
- Stuart Warmington, Deakin University

Publishers

Our thanks and acknowledgment go to the McGraw-Hill Education Australia team who made this book possible. The publication of a work of this scope would not have been possible without them.

We appreciate the work of our Publisher Robert Ashworth, for his vision and faith in this project, and our Product Developers Samantha Allemann and Jane Roy, for their organisational skills and enthusiasm for the project.

Our thanks to Production Editor Tamiko Rex for her methodical project management during production; to Dominic Giustarini, our Design Coordinator; Marisa Rey Bulen and Belinda Lum, from the Digital Production team; our copyeditor, Rosemary Moore; and Sarah Long, Marketing Manager.

About the Authors

Scott K. Powers is a Distinguished Professor and the UAA Endowed Professor in the Department of Applied Physiology and Kinesiology at the University of Florida. Powers enjoys teaching and has earned three University of Florida teaching awards. Powers' research has focused on exercise-mediated changes in cardiac and skeletal muscle antioxidant systems and the role that these changes play in providing protection against oxidant injury. Further, he is actively investigating the mechanisms responsible for respiratory muscle weakness in patients subjected to prolonged periods of mechanical ventilation. Powers' laboratory work has been funded by grants totalling more than five million dollars from the National Institute of Health, American Heart Association, American Lung Association and the Florida Biomedical Research Program, and this research has resulted in more than 180 peer-reviewed research publications. He is also active in both the American Physiological Society and the American College of Sports Medicine. Powers has co-authored four college textbooks for use in exercise physiology and fitness courses. He is an Associate Editor for the *American Journal of Physiology—Regulatory, Comparative, and Integrative Physiology* and a member of the editorial board for the *Journal of Applied Physiology*, the *International Journal of Sports Medicine* and the *International Journal of Sport Nutrition and Exercise Metabolism*. Scott Powers received his Bachelor's Degree in Physical Education from Carson Newman College, his Master's Degree in Exercise Physiology from the University of Georgia, and a Doctorate (EdD) in Exercise Physiology from the University of Tennessee. Powers earned a second Doctoral Degree (PhD) in Physiology from Louisiana State University.

Edward T. Howley received his BS degree from Manhattan College and his MS and PhD degrees from the University of Wisconsin, Madison. He completed a one-year post-doctoral appointment at Penn State University and began his career at the University of Tennessee in 1970. He taught a variety of courses in physiology, exercise physiology and fitness testing and prescription over 36 years. He also served as an administrator of the Exercise Science program/department. He retired in 2007 and holds the rank of Professor Emeritus. He has received several awards for his teaching. Most of Dr. Howley's volunteer efforts have been with the American College of Sports Medicine, where he served as President from 2002–03. He is the Editor-in-Chief of *ACSM's Health & Fitness Journal*, and is chair of the program planning committee for the annual ACSM Health & Fitness Summit meeting.

Local Authors

Jim Cotter is an Associate Professor of Exercise and Environmental Physiology at the School of Physical Education, Sport and Exercise Sciences, University of Otago. He completed his PhD in Australia, and worked as a Research Scientist in the Defence Science & Technology Organisation (Melbourne) researching heat stress and its mitigation during physically-demanding work in the tropics. Having returned to his alma mater in 2001, he enjoys the interdependency of teaching, research and service in academia, especially research supervision and collaboration across disciplines. His research interests focus on unravelling the role of stressors within exercise to understand them more fully and how different environments affect people acutely and chronically (especially heat, dehydration and hypoxia). Jim chooses to work in both health and performance contexts because each provides different insights and applications to the physiology of exercise.

Xanne Janse de Jonge is an academic in Exercise and Sport Science at the University of Newcastle. She studied Exercise Physiology at the VU University Amsterdam and moved to Australia to complete her PhD on the effects of the menstrual cycle on exercise performance. Although her research still focuses on this topic, Xanne is also collaborating with the Central Coast Mariners Football Club and the Judo Federation of Australia on applied sport science research. Xanne's professional experience as an Exercise Physiologist has led to her interest in clinical research, including diabetes and core stability training for chronic low back pain.

Anthony Leicht is an Associate Professor within the Institute of Sport and Exercise Science at James Cook University. He is an experienced exercise scientist/researcher of international repute and has expertise in the responses to exercise, with a particular emphasis on cardiovascular physiology, including heart rate control. His research foci include topics that reflect his teaching interests of exercise physiology, health and exercise testing. He is a current member of several national and international professional bodies associated with exercise science and physiology, a former international and national basketball referee and an avid sports fan.

Toby Mündel is a passionate educator at Massey University's School of Sport and Exercise in Aotearoa New Zealand. His teaching and research interests focus on the physiological responses to exercise, extreme environments and agents affecting the central nervous system. He aims to help better understand how performance can be improved and how risks to health can be minimised. He teaches undergraduate and graduate classes and has helped train 10 masterate/doctoral research students in these topics. He enjoys leading an anti-sloth lifestyle with his family, especially outdoors, exploring new countries and cultures, eating and cooking, smiling and laughing and drinking tea!

Kate Pumpa is an Assistant Professor of Exercise Physiology in the Discipline of Sport and Exercise Science, University of Canberra. She is an Accredited Exercise Physiologist and Accredited Sports Dietitian, who has extensive experience in Rugby Union sports nutrition and recovery strategies to enhance sporting performance. Her research focuses on two distinct areas: the evaluation and application of assessing energy expenditure in athletes to assist with nutrition prescription, and the evaluation of different exercise interventions to enhance quality of life in people with chronic diseases, particularly those with cancer. Kate is on the editorial board for the *Journal of Science and Medicine in Sport*, a consultant Sports Dietitian to the Australian Rugby Union, and the fitness expert for the *Australian Women's Health Magazine*.

Ben Rattray is an Assistant Professor within the Discipline of Sport and Exercise Science at the University of Canberra. He initially began his career as a sports scientist working with a number of groups including the ACT Academy of Sport before moving to Glasgow to work with the Scottish Institute of Sport. More recently Ben completed his doctoral studies at the University of Sydney investigating the effects of different exercise stressors on mitochondrial function. Now at the University of Canberra, he teaches exercise physiology and health and oversees a number of research programs. Ben's research interests span the sport and health divide of exercise physiology and he collaborates with groups such as the Australian Institute of Sport working across areas such as post-exercise recovery, exercise and the brain, and the relationship between physical activity and dementia. He is currently a member of several national and international professional bodies associated with exercise science and physiology, a former international athlete and a lover of the outdoors.

Digital Resources

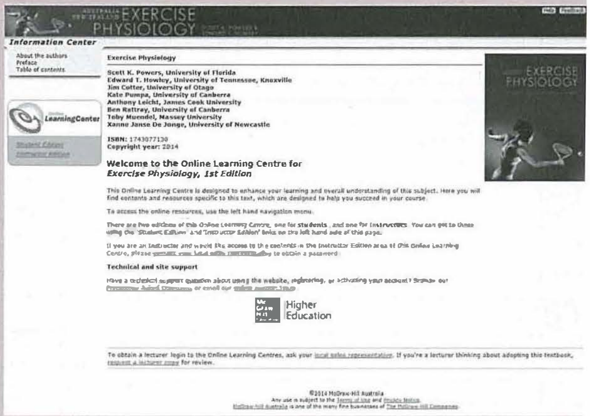
The Online Learning Centre (OLC) that accompanies this text is an integrated online product to assist you in getting the most from your course, providing a powerful learning experience that goes beyond the text: **www.mhhe.com/au/powers1e**

Testbank

This computerised package allows instructors to custom design, save and generate tests. The program permits instructors to edit, add or delete questions from the testbank thereby customising tests for their students.
Authored by Michael Simmonds, Griffith University.

Instructor Resource Manual

The instructor resource manual provides detailed teaching notes that lecturers can use to customise their lectures. It contains activities for inside and outside of the classroom, as well as additional sources relating to the chapter content.
Authored by Ajmol Ali, Massey University.



Exercise Physiology

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Anthony Leicht, James Cook University
Ben Rattray, University of Canberra
Toby Muendel, Massey University
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Welcome to the Online Learning Centre for
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This Online Learning Centre is designed to enhance your learning and overall understanding of this subject. Here you will find contents and resources specific to this text, which are designed to help you succeed in your course.

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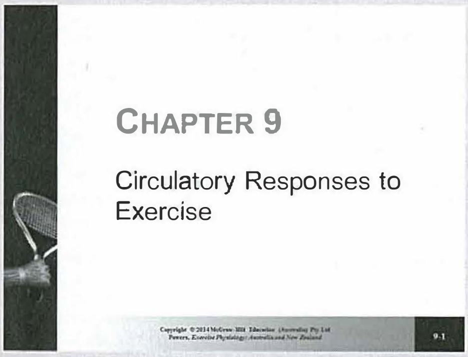

CHAPTER 9

Circulatory Responses to Exercise

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Powers, *Exercise Physiology: Australia and New Zealand*

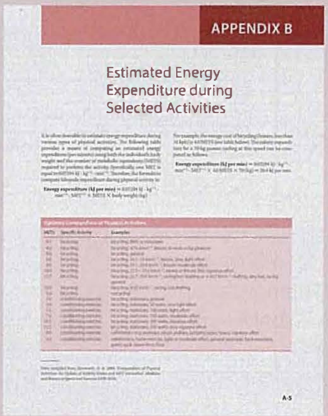
9-1

Powerpoint

A set of **PowerPoint®** slides accompanies each chapter and provides a lecture outline, plus key figures and tables from the text. These slides can be customised to meet course and instructor needs, or used as a revision tool that summarises core concepts from each chapter.
Authored by Ajmol Ali, Massey University.

Appendices

These appendices provide additional information, guidelines and calculations that will aid students throughout their studies. Where relevant, these appendices are referenced throughout the text.



APPENDIX B

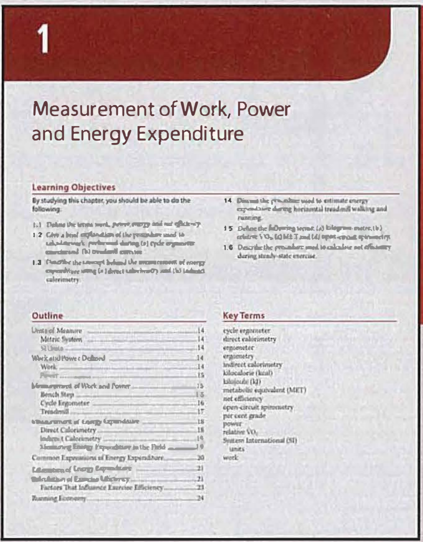
Estimated Energy Expenditure during Selected Activities

A-5

Animations

A series of animations are provided to help students visualise concepts and processes, including glucose regulation, respiration, gas exchange and muscle contraction.

Text at a Glance



1

Measurement of Work, Power and Energy Expenditure

Learning Objectives

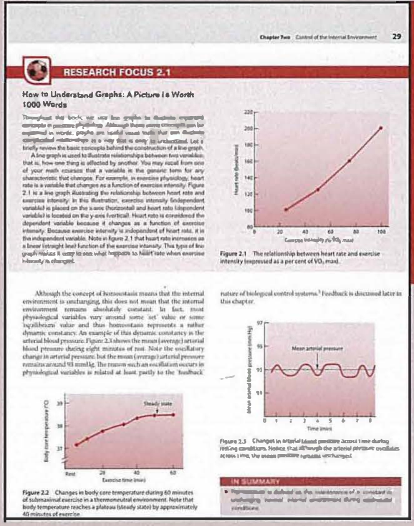
Outline

Key Terms

cycle ergometer
direct calorimetry
ergometer
ergometry
indirect calorimetry
kilocalorie (kcal)
kilojoule (kJ)
metabolic equivalent (MET)
net efficiency
open-circuit spirometry
per cent grade
power
relative $\dot{V}O_2$
System International (SI) units
work

Learning Objectives, Chapter Outlines and Key Terms

These elements appear at the start of each chapter and preview the content that follows, focusing students' attention on the key concepts and terms to be discussed in the chapter.



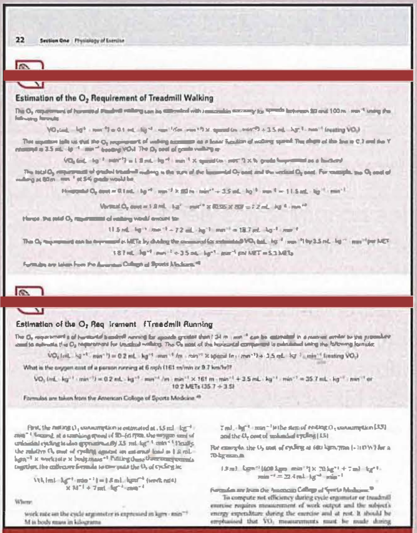
Chapter Two Control of the Internal Environment 29

RESEARCH FOCUS 2.1

How to Understand Graphs: A Picture Is Worth 1000 Words

Research Focus

No matter what their career direction, students must learn how to read and think about the latest research. Research Focus presents new research and explains why it is relevant.



Estimation of the O_2 Requirement of Treadmill Walking

Estimation of the O_2 Requirement of Treadmill Running

A Closer Look

A Closer Look offers an in-depth view of topics that are of special interest to students. This feature encourages students to dig deeper about key concepts.

ASK THE EXPERT 4.1

Oxygen Uptake Kinetics at the Onset of Constant Work-Rate Exercise: Questions and Answers with Dr. Bruce Gladden

Ask the Expert

This question-and-answer feature lets students find out what leading scientists have to say about topics such as the effect of space flight on skeletal muscle and the effect of exercise on bone health.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CLINICAL APPLICATIONS 4.1

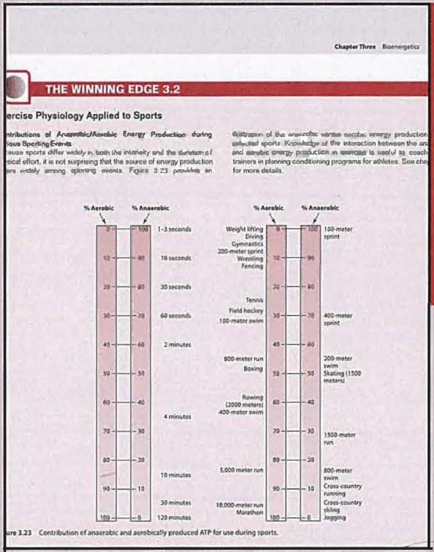
McArdle's Syndrome: A Genetic Error in Muscle Glycogen Metabolism

Exercise Duration and Fuel Selection

Interaction of Fat/Carbohydrate Metabolism

Clinical Applications

This feature shows how the concepts being learned in exercise physiology are applied in a clinical setting.


Chapter Three Bioenergetics

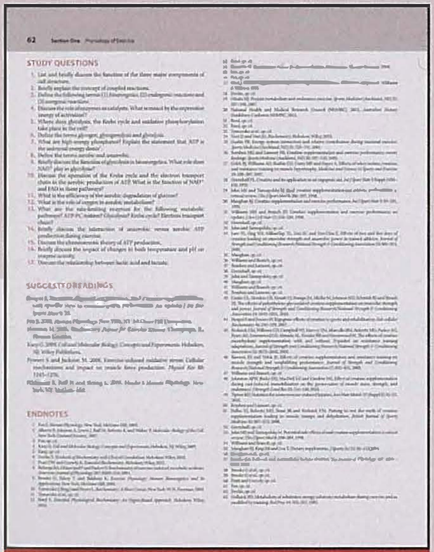
THE WINNING EDGE 3.2

ercise Physiology Applied to Sports

ure 3.23 Contribution of anaerobic and aerobically produced ATP for use during sports.

The Winning Edge

How do athletes find the 'extra edge' that can make the difference between victory and defeat? This feature explains the science behind a winning performance.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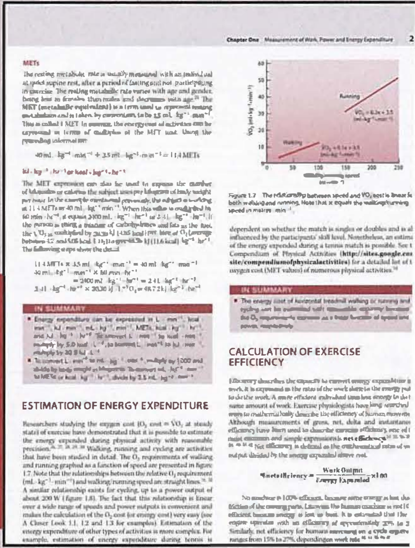
STUDY QUESTIONS

SUGGESTED READINGS

ENDNOTES

Study Questions

These questions allow students to check their understanding of the chapter contents, apply skills they are learning and develop their critical thinking skills.


Chapter One Measurement of Work, Power and Energy Expenditure

METs

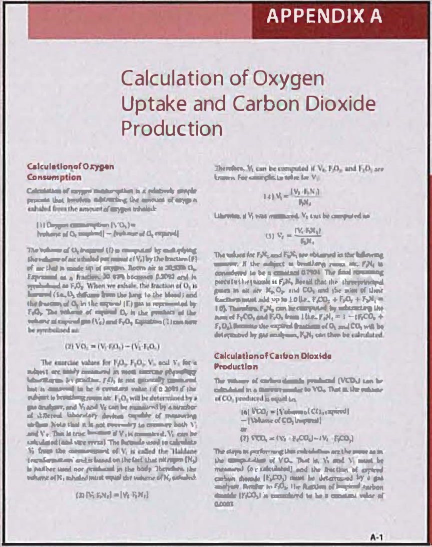
IN SUMMARY

ESTIMATION OF ENERGY EXPENDITURE

CALCULATION OF EXERCISE EFFICIENCY

In Summary

End-of-section summaries aid student revision and summarise core concepts before moving on to the next topic.


APPENDIX A

Calculation of Oxygen Uptake and Carbon Dioxide Production

Calculation of Oxygen Consumption

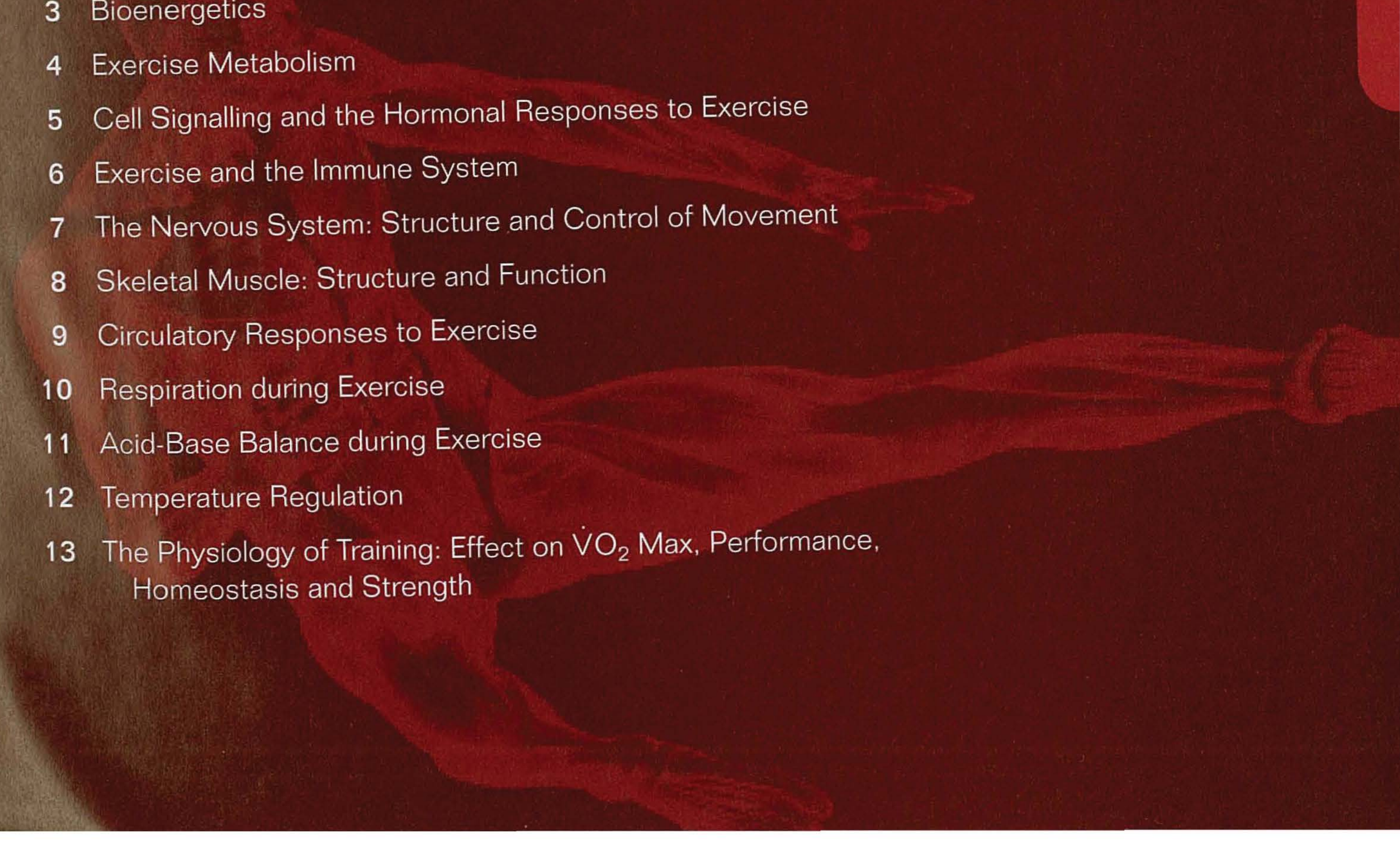
Calculation of Carbon Dioxide Production

A-1

Appendices

Located online these appendices provide additional information, guidelines and calculations that will aid students throughout their studies. Where relevant, these appendices are referenced throughout the text.

Physiology of Exercise



Introduction to Exercise Physiology

Learning Objectives

By studying this chapter, you should be able to do the following:

I.1 Describe the scope of exercise physiology as a branch of physiology.

I.2 Describe the influence of European scientists on the development of exercise physiology.

I.3 List career options for students majoring in exercise science, sport science or exercise physiology.

Outline

Does one have to have a 'genetic gift' of speed to be a world-class runner or is it all due to training? What happens to your heart rate when you take an exercise test that increases in intensity each minute? What changes occur in your muscles as a result of an endurance-training program that allows you to run at faster speeds over longer distances? What fuel—carbohydrate or fat—is most important when running the marathon? Research in exercise physiology provides answers to these and similar questions.

Physiology is the study of the function of tissues (e.g. muscle, nerve), organs (e.g. heart, lungs) and systems (e.g. cardiovascular system). Exercise physiology extends this to evaluate the effect of a single bout of exercise (acute exercise) and repeated bouts of exercise (e.g. chronic exercise, or training) on these tissues, organs and systems. In addition, the responses to acute exercise and training may be studied at high altitude or in extremes of heat and humidity to determine the impact of these environmental factors on our ability to respond and adapt to exercise. Finally, studies are conducted on young and old individuals, both healthy and those with disease, to understand the role of exercise in the prevention of, or rehabilitation from, various chronic diseases.

Consistent with this perspective, we go beyond simple statements of fact to show how information about the physiology of exercise is applied to the prevention of and rehabilitation from coronary heart disease, the performances of elite athletes and the ability of a person to work in adverse environments such as high altitudes. The acceptance of terms such as *sports physiology, sports nutrition and sports medicine* is evidence of the growth of interest in the application of physiology of exercise to real-world problems. Careers in sport science, clinical exercise physiology and strength and conditioning, as well as the traditional fields of physiotherapy and medicine, are of interest to students studying exercise physiology. We will expand on career opportunities later in the chapter.

In this chapter, we provide a brief history of exercise physiology to help you understand where we have been and where we are going. In addition, throughout the text a variety of scientists and clinicians are highlighted in a historical context as subject matter is presented (i.e. muscle, cardiovascular responses, altitude). We hope that by linking a person to a major accomplishment within the context of a chapter, history will come alive and be of interest to you.

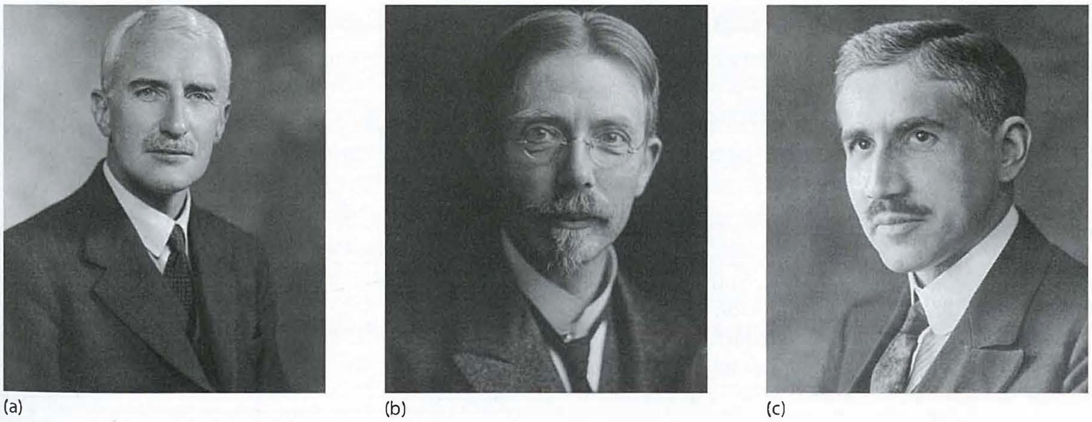
BRIEF HISTORY OF EXERCISE PHYSIOLOGY

The history of exercise physiology represents a global perspective involving scientists from many different countries. In this section we begin with the impact European scientists have had on the development of exercise physiology. We then describe the role of the Harvard Fatigue Lab in the growth of exercise physiology in the US as well as contemporary influences on exercise physiology across the world.

European Heritage

A good starting place to discuss the history of exercise physiology is Europe. Three scientists, A. V. Hill of Britain, August Krogh of Denmark and Otto Meyerhof of Germany, received Nobel Prizes for research on muscle or muscular exercise.[1] Hill and Meyerhof shared the Nobel Prize in Physiology or Medicine in 1922. Hill was recognised for his precise measurements of heat production during muscle contraction and recovery, and Meyerhof for his discovery of the relationship between the consumption of oxygen and the measurement of lactic acid in muscle. Hill was trained as a mathematician before becoming interested in physiology. In addition to his work cited for the Nobel Prize, his studies on humans led to the development of a framework around which we understand the physiological factors related to distance-running performance[2] (see chapter 19).

Although Krogh received his Nobel Prize for his research on the function of capillary circulation, he had a major impact on numerous areas of investigation. Further, like many productive investigators, his influence was not due only to his own work, but to that of his students and colleagues as well. Krogh's collaboration with Johannes Lindhard resulted in classic studies dealing with carbohydrate and fat metabolism during exercise, and how the cardiovascular and respiratory systems' responses are controlled during exercise.[3] Three of Krogh's students, Erling Asmussen, Erik Hohwü-Christensen and Marius Nielsen (called the three musketeers by Krogh), had a major impact on exercise physiology research throughout the middle of the twentieth century. These investigators, in turn, trained a number of outstanding physiologists, several of whom you will meet throughout


(a) (b) (c)

(a) Archibald V. Hill, (b) August Krogh, (c) Otto F. Meyerhof this text. The August Krogh Institute in Denmark contains some of the most prominent exercise physiology laboratories in the world. Marie Krogh, his wife, was a noted scientist in her own right and was recognised for her innovative work on measuring the diffusing capacity of the lung. We recommend the biography of the Kroghs written by their daughter, Bodil Schmidt-Nielsen (see Suggested Readings), for those interested in the history of the physiology of exercise.

Several other European scientists must also be mentioned, not only because of their contributions to the physiology of exercise, but because their names are commonly used in a discussion of exercise physiology. J. S. Haldane did some of the original work on the role of CO_2 in the control of breathing. Haldane also developed the respiratory gas analyser that bears his name.[4] C. G. Douglas did pioneering work with Haldane in the role of O_2 and lactic acid in the control of breathing during exercise, including some work conducted at various altitudes. The canvas-and-rubber gas collection bag used for many years in exercise physiology laboratories around the world carries Douglas's name. A contemporary of Douglas, Christian Bohr of Denmark, did the classic work on how O_2 binds to haemoglobin. The 'shift' in the oxygen-haemoglobin dissociation curve due to the addition of CO_2 bears his name (see chapter 10). Interestingly, it was Krogh who did the actual experiments that enabled Bohr to describe his famous 'shift'.[5, 6]

The 'three musketeers': From left to right: Erling Asmussen, Erik Hohwü-Christensen and Marius Nielsen.

IN SUMMARY

- A. V. Hill, August Krogh and Otto Meyerhof received the Nobel Prize for work related to muscle or muscular exercise.
- Numerous European scientists have had a major impact on the field of exercise physiology.

Harvard Fatigue Laboratory

A focal point in the history of exercise physiology in the US was the Harvard Fatigue Laboratory. Professor L. J. Henderson organised the laboratory within the Business School to conduct physiological research on industrial hazards. Dr. David Bruce Dill was the research director from the time the laboratory opened in 1927 until it closed in 1947.[7] Table I.1 shows that the scientists conducted research in numerous areas, in the laboratory and in the field, and the results of those early studies have been supported by more recent investigations. Dill's classic text, *Life, Heat and Altitude,*[8] is recommended reading for any student of exercise and environmental physiology. Much of the careful and precise work of the laboratory was conducted using the now-classic Haldane analyser for respiratory gas analysis and the van Slyke apparatus for blood-gas analysis. The advent of computer-controlled equipment in the 1980s has made data collection easier but has not improved on the accuracy of measurement (see figure I.1).

David Bruce Dill

TABLE I.1	**Active Research Areas in the Harvard Fatigue Laboratory**

- Metabolism
  - Maximal oxygen uptake
  - Oxygen debt (now termed Excess Post-exercise Oxygen Consumption or EPOC)
  - Carbohydrate and fat metabolism during long-term work
- Environmental physiology
  - Altitude
  - Dry and moist heat
  - Cold
- Clinical physiology
  - Gout
  - Schizophrenia
  - Diabetes mellitus
- Ageing
  - Basal metabolic rate
  - Maximal oxygen uptake
  - Maximal heart rate
- Blood
  - Acid-base balance
  - O_2 saturation: role of pO_2, pCO_2 and carbon monoxide
  - Nutrition assessment techniques
  - Vitamins
  - Foods
- Physical fitness
  - Harvard Step Test

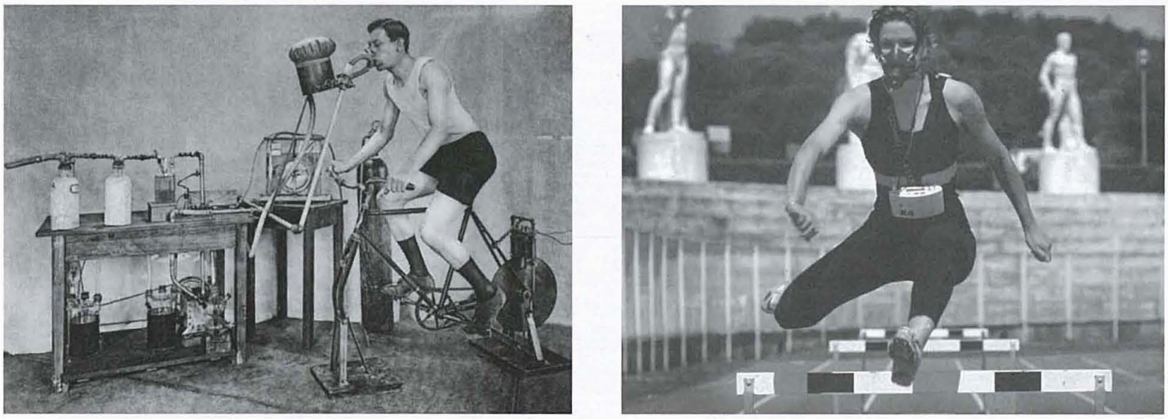


Figure I.1 Comparison of old and new technology used to measure oxygen consumption and carbon dioxide production during exercise. (*Left*: The Carnegie Institute of Washington, D.C.; *Right*: COSMED.)

The Harvard Fatigue Laboratory attracted doctoral students as well as scientists from other countries. Many of the alumni from the laboratory are recognised in their own right for excellence in research in the physiology of exercise. Two doctoral students, Steven Horvath and Sid Robinson, went on to distinguished careers at the Institute of Environmental Stress in Santa Barbara and Indiana University, respectively.

Foreign 'Fellows' included the 'three musketeers' mentioned in the previous section (E. Asmussen, E. Hohwü-Christensen and M. Nielsen) and the Nobel Prize winner August Krogh. These scientists brought new ideas and technology to the lab, participated in laboratory and field studies with other staff members, and published some of the most important work in the physiology of exercise between 1930 and 1980. Rudolpho Margaria, from Italy, went on to extend his classic work on oxygen debt and described the energetics of locomotion. Peter F. Scholander, from Norway, gave us his chemical gas analyser that is a primary method of calibrating tank gas used to standardise electronic gas analysers.[9]

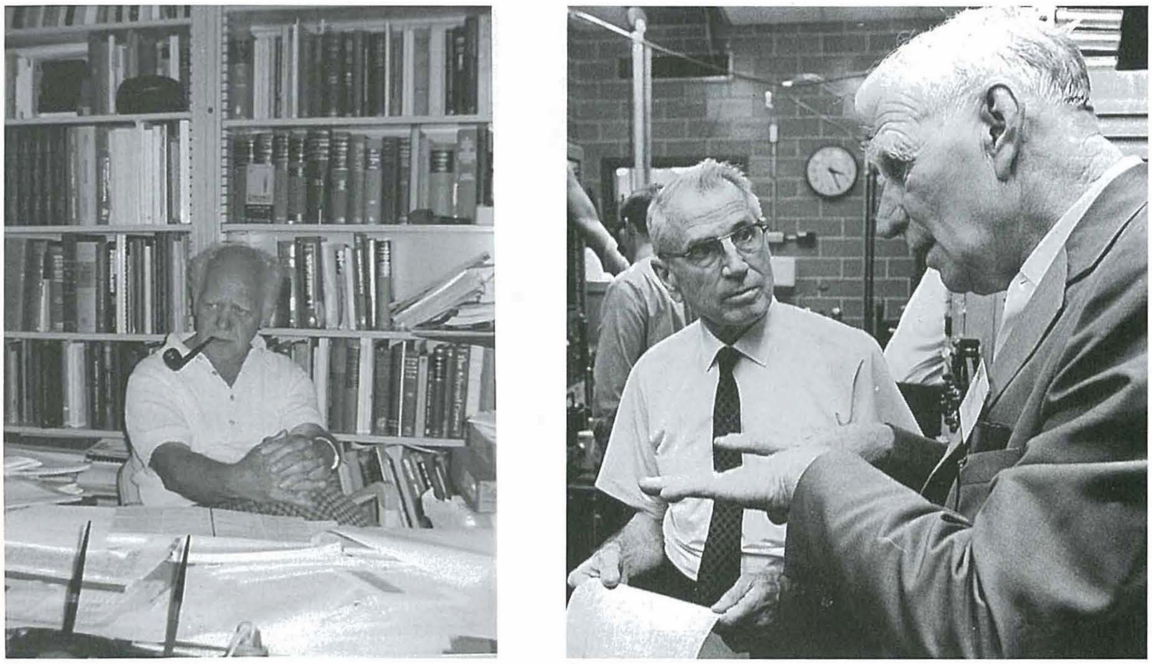
In summary, under the leadership of Dr. D. B. Dill, the Harvard Fatigue Laboratory became a model for research investigations into exercise and environmental physiology, especially as it relates to humans. When the laboratory closed and the staff dispersed, the ideas, techniques and approaches to scientific inquiry were distributed throughout the world and with them, Dill's influence in the area of environmental and exercise physiology. Dr. Dill continued his research outside Boulder City, Nevada, into the 1980s. He died in 1986 at the age of 93.

Antipodean Influences

In 1981 the Australian Institute of Sport (AIS) opened in Canberra, prompted in part by the 1976 Montreal Olympics, in which the Australian team failed to win a gold medal, leaving the nation embarrassed by this sporting low point. While the AIS has influenced numerous athletes, coaches and sports, it has also had an influence on exercise physiology in the region. Along with the associated state sport institute and academy network, the AIS has been regarded as a place that has driven sport science development and research in Australia. The AIS is associated with a number of world-renowned sport scientists, trained many more, and inspires many undergraduates studying in the area. Researchers such as Professor Chris Gore have become world leaders in athletes' use of altitude training methods, and the AIS is a now a place in which researchers from around the world seek to collaborate. More recently, the use of exercise or physical activity has become increasingly important in preventing and assisting in the treatment of chronic diseases. In Australia, Sports Medicine Australia and Exercise and Sport Science Australia (ESSA) (www.essa.org.au) have helped develop many new opportunities and careers within the clinical setting. The equivalent organisations in New Zealand are Sports Medicine New Zealand (www.sportsmedicine.co.nz) and Sport and Exercise Science New Zealand (SESNZ) (www.sesnz.org.nz). While SESNZ offers accreditations in exercise science, these do not yet receive the same scope for government-level recognition and remuneration as ESSA accreditation does. Institutions across Australia and New Zealand conduct many courses in these areas along with world-class experts conducting related research.

Contemporary approaches to research in exercise physiology are often cross-disciplinary, requiring the expertise of teams of individuals. For instance, while fatigue has often been thought of as originating in muscle, new methodologies are revealing how much the brain is involved in the fatigue process.[10] Similarly, advances in the fields of genetics are increasingly revealing how we adapt to training.[11] Other recent research is revealing the risks of sitting for too long or sedentary behaviour.[12] Modern research teams often integrate a range of expertise and this makes for fascinating exercise physiology wherever you are in the region—or, indeed, wherever you are in the world.

Progress towards understanding any issue in exercise physiology transcends time, national origin and scientific training. Solutions to difficult questions require the interaction of scientists from diverse disciplines and professions such as physiology, biochemistry, molecular biology and medicine. We recommend *Exercise Physiology—People and Ideas* (see the Suggested Readings) to further your understanding of important historical connections. In this book, internationally known scientists provide a historical treatment of a number of important issues in exercise physiology with an emphasis on the cross-continent flow of energy and ideas. We highlight several scientists and clinicians with our Ask the Expert boxes throughout the text, both to introduce them to you and for them to share their current ideas. In addition, A Look Back—Important People in Science,


(a) (b)

(a) Steven Horvath, (b) Sid Robinson (left) in his lab, talking with A. C. Burton.

is used to recognise well-known scientists who have influenced our understanding of exercise physiology. In this context you will get to know those who have gone before and those who are currently leading the charge.

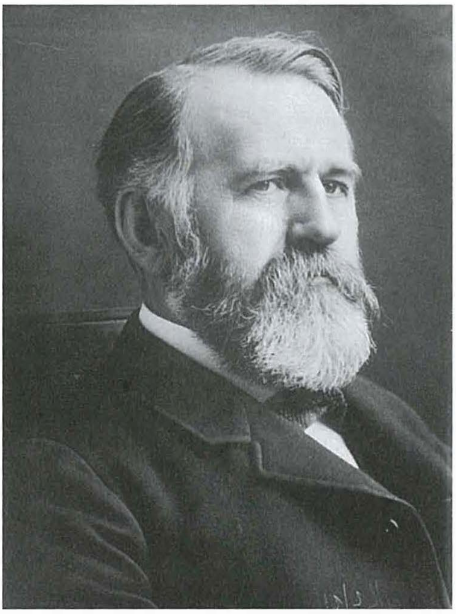
IN SUMMARY

- The Harvard Fatigue Laboratory was a focal point in the development of exercise physiology in the US. Dr. D. B. Dill directed the laboratory from its opening in 1927 until its closing in 1947. The body of research in exercise and environmental physiology produced by the scientists in that laboratory formed the foundation for new ideas and experimental methods that still influence us today. A similar focus was developed in Australia in 1981 with the opening of the AIS to advance the sporting prowess of Australian athletes based on sound principles of exercise and sport science.

PHYSIOLOGY, PHYSICAL FITNESS AND HEALTH

Physical fitness is a popular topic today and its popularity has been a major factor in motivating university students to pursue careers in exercise science, exercise physiology, sport science, physical education, nutrition, physiotherapy and medicine. In the 2007–08 National Health Survey, 72% of Australians aged 15 years and over were classified as sedentary or having low exercise levels.[13] Since then, it has been reported that 63.4% of Australians over the age of 18 are overweight or obese; consequently, obesity is now a national health priority in Australia.[14] While it is acknowledged that survey information has various limitations, it seems that while New Zealand adults may be more active than their Australian counterparts, the prevalence of overweight and obesity in New Zealand is on par with Australia. Specifically, in the New Zealand Health Survey 2011–12, 54% of adults (aged 15 years and over) reported that they undertake at least 30 minutes of moderate-intensity physical activity at least five days per week; the figures are lower for Pacific women and Asian adults of both sexes, and ~12% of adults are sedentary. On the other hand, 64% of adults are overweight or obese; these rates are the same for both sexes, both having risen since 2006–07, along with the incidence of type 2 diabetes.[15] Concerns about physical fitness are not new, with American researchers taking an interest in physical fitness more than one hundred years ago and Australian and New Zealand researchers examining this area much later.[16, 17] Between the Civil War and the First World War (WWI), physical education in the US was primarily concerned with the development and maintenance of fitness and many of the leaders in physical education were trained in medicine[18] (p. 5). For example, Dr. Dudley Sargent, hired by Harvard University in 1879, set up a physical training program with individual exercise prescriptions to improve a person's structure and function to achieve 'that prime physical condition called fitness—fitness for work, fitness for play, fitness for anything a man may be called upon to do'[19] (p. 297).

Sargent was clearly ahead of his time in promoting health-related fitness. Later, war became a primary force driving that country's interest in physical fitness. Concerns about health and fitness were raised during WWI and WWII when large numbers of draftees failed the induction exams due to mental and physical defects[20] (p. 407). These concerns influenced the type of physical education programs in the schools during these years, making them resemble premilitary training programs[21] (p. 484). Interestingly, whereas stunted growth and being underweight were major reasons



Dudley Sargent

for rejecting military recruits in WW II, obesity is the major cause for rejecting recruits today.

The present interest in physical activity and health was stimulated in the early 1950s by two major findings:[1] autopsies of young soldiers killed during the Korean War showed that significant coronary artery disease had already developed[2] and, Hans Kraus showed that American children performed poorly on a minimal muscular fitness test compared to European children[22] (p. 516). Due to the latter finding, President Eisenhower initiated a conference in 1955 that resulted in the formation of the President's Council on Youth Fitness. The American Association for Health, Physical Education and Recreation (AAHPER) supported these activities and in 1957 developed the AAHPER Youth Fitness Test with national norms to be used in physical education programs throughout the country. Before he was inaugurated, President Kennedy expressed his concerns about the nation's fitness in an article published in *Sports Illustrated*, called 'The Soft American'.[23]

> For the physical vigor of our citizens is one of America's most precious resources. If we waste and neglect this resource, if we allow it to dwindle and grow soft, then we will destroy much of our ability to meet the great and vital challenges which confront our people. We will be unable to realize our full potential as a nation.

During Kennedy's term, the council's name was changed to the 'President's Council on Physical Fitness' to highlight the concern for fitness. The name was changed again in the Nixon administration to the 'President's Council on Physical Fitness and Sports', which supported fitness not only in schools but in business, industry and for the general public (see www.fitness.gov). The name was most recently changed by President Obama to the 'President's Council on Fitness, Sports, & Nutrition' to focus more attention on the obesity epidemic. Items in the Youth Fitness Test were changed over the years and in 1980 the American Alliance for Health, Physical Education, Recreation and Dance (AAHPERD) published a separate *Health-Related Physical Fitness Test Manual*[24] to distinguish between 'performance testing' (e.g. 50-yard dash) and 'fitness testing' (e.g. skinfold thickness). This health-related test battery is consistent with the direction of lifetime fitness programs, being concerned with obesity, cardiorespiratory fitness and low-back function. A parallel fitness test, FitnessGram®, was developed by The Cooper Institute in 1982, including software to support the scoring and printing of reports (see www.fitnessgram.net/home). Within Australia, a similar generic battery of fitness tests was developed for the Australian Fitness Education Award in the late 1980s. For readers interested in the history of fitness testing in schools within the US, Park's monograph in the Suggested Readings is recommended.

Paralleling this interest in the physical fitness of youth was the rising concern about the death rate from coronary heart disease in the middle-aged American, Australian and New Zealand populations. Epidemiological studies of the health status of the population underscored the fact that degenerative diseases related to poor health habits (e.g. high-fat diet, smoking, inactivity) were responsible for more deaths than the classic infectious and contagious diseases. In 1966, a major symposium highlighted the need for more research in the area of physical activity and health.[25] In the 1970s, there was an increase in the use of exercise tests to diagnose heart disease and to aid in the prescription of exercise programs to improve cardiovascular health. Large corporations developed corporate health programs to improve the health status of that high-risk group. While most Americans, Australians and New Zealanders are now familiar with such programs and some students of exercise physiology seek careers in 'Corporate Fitness', such programs are not new. The photo in figure I.2, taken from the 1923 edition of McKenzie's *Exercise in Education and Medicine*,[26] shows a group of businessmen in costume doing dance exercises. In short, the idea that regular physical activity is an important part of a healthy lifestyle was 'rediscovered'. If any questions remained about the importance of physical activity to health, the publication of the Surgeon General's Report in 1996 and the appearance of the first US Physical Activity Guidelines in 2008 put them to rest (see A Closer Look I.1).

Figure I.2 A group of businessmen in a dancing class under the direction of Oliver E. Hebbert.

A CLOSER LOOK I.1

By the early to mid-1980s, it had become clear that physical inactivity was a major public health concern.[27] In 1992, the American Heart Association made physical inactivity a major risk factor for cardiovascular diseases, just like smoking, high blood pressure and high serum cholesterol.[28] The Heart Foundation in Australia and Heart Foundation New Zealand quickly followed suit. In 1995, the Centers for Disease Control and Prevention (CDC) and the American College of Sports Medicine published a public health physical activity recommendation that 'Every U.S. adult should accumulate 30 minutes or more of moderate-intensity physical activity on most, preferably all, days of the week'.[29] A year later, the *Surgeon General's Report on Physical Activity and Health* was published.[30]

This report highlighted the fact that physical inactivity was killing US adults and the problem was a big one—60% of US adults did not engage in the recommended amount of physical activity and 25% were not active at all. This report was based on the large body of evidence available from epidemiological studies, small-group training studies and clinical investigations showing the positive effects of an active lifestyle. For example, physical activity was shown to:

- lower the risk of dying prematurely and from heart disease
- reduce the risk of developing diabetes and high blood pressure
- help maintain weight and healthy bones, muscles and joints
- help lower blood pressure in those with high blood pressure and promote psychological well-being.

In 2001, the first Physical Activity Guidelines for Australians were developed[31] and outlined the minimum levels of physical activity required to gain a health benefit and ways to incorporate incidental physical activity into everyday life.[32]

IN SUMMARY

- Fitness has been an issue in westernised countries from the latter part of the nineteenth century until the present. War, or the threat of war, exerted a strong influence on fitness programs in the public schools in the US. In WW II, being underweight and small of stature were major reasons for rejecting military recruits; today, obesity is a major cause for rejection.
- Recent interest in fitness is related to the growing concern over the high death rates from disease processes that are attributable to preventable factors, such as poor diet, lack of exercise and smoking. Government and professional organisations have responded to this need by educating the public about these problems.

PHYSICAL EDUCATION TO EXERCISE SCIENCE

Undergraduate academic preparation in exercise science has changed over the past five decades to reflect the explosion in the knowledge base related to the physiology of exercise, biomechanics and exercise prescription. This occurred at a time of a perceived reduced need for school-based physical education teachers and an increased need for exercise professionals in the preventive and clinical settings. These factors, as well as others, led some university departments to change their names from Physical Education to Human Movement or Exercise Science. For example, New Zealand's oldest such school, established in 1948, extended its name in 2013 to the School of Physical Education, Sport and Exercise Sciences to reflect the change in emphasis. This trend is likely to continue as programs move further away from traditional roots in education and become integrated within faculties of Medicine, Science or Allied Health.[33] In many universities, little difference now exists between the first two years of requirements in physiotherapy or pre-medical pathways and the path associated with exercise and sporting professions. The differences among these pathways lie in the 'application' courses that follow. Biomechanics, physiology of exercise, fitness assessment, exercise prescription, strength and conditioning and so on belong to the exercise science conduit. However, it must again be pointed out that this new trend is but another example of a rediscovery of old roots rather than a revolutionary change. Kroll describes two 4-year professional physical education programs in the 1890s, one at Stanford and the other at Harvard, that were the forerunners of today's programs[34] (pp. 51–64). They included the detailed scientific work and application courses with clear prerequisites cited. Finally, considerable time was allotted for laboratory work. No doubt, Lagrange's 1890 text, *Physiology of Bodily Exercise*,[35] served as an important reference source for these students. The expectations and goals of those programs were almost identical to those specified for current exercise physiology undergraduate tracks. In fact, one of the aims of the Harvard program was to allow a student to pursue the study of medicine after completing two years of study[36] (p. 61).

GRADUATE STUDY AND RESEARCH IN THE PHYSIOLOGY OF EXERCISE

While the Harvard Fatigue Laboratory was closing in 1947, the US was on the verge of a tremendous expansion in the number of universities offering graduate study and research opportunities in exercise physiology. A 1950 survey showed that only 16 colleges or universities in the US had research laboratories in departments of physical education.[37] By 1966, 151 institutions had research facilities, 58 of them in exercise physiology[38] (p. 526). This expansion was due to the availability of more scientists trained in the research methodology of exercise physiology, the increased number of students attending college due to the GI Bill and student loans and the increase in federal dollars to improve the research capabilities of universities.[39, 40]

'The scholar's work will be multiplied many fold through the contribution of his students.' This quote, taken from Montoye and Washburn,[41, 42] expresses a view that has helped attract researchers and scholars to universities. Evidence to support this quote was presented in the form of genealogical charts of contributors to the *Research Quarterly*.[43] These charts showed the tremendous influence a few people had through their students in the expansion of research in physical education. Probably the best example of this is Thomas K. Cureton, Jr., of the University of Illinois, a central figure in the training of productive researchers in exercise physiology and fitness (see A Look Back—Important People in Science).

It should be no surprise that the major issues studied by researchers in exercise physiology have changed over the years. Table I.2, from Tipton's look at the fifty years following the closing of the Harvard Fatigue Lab, shows the subject matter areas that were studied in considerable detail between 1954 and 1994.[44] A great number of these topics fit into the broad area of systemic physiology or were truly applied physiology issues. Although research continues to take place in most of these areas, Tipton believes that many of the most important questions to be addressed in the future will be answered by those with special training in molecular biology. Baldwin[45] supported Tipton's viewpoint and provided a summary of important questions dealing with exercise and chronic disease whose answers are linked to functional genomics and proteomics, important new tools for the molecular biologist. However, he also noted the need for increased research to address physical activity and chronic diseases at the lifestyle and behavioural levels. This 'integrated' approach, crossing disciplines and technologies, should be reflected in the academic programs educating the next generation of exercise science students. We recommend the chapters by Tipton[46] and Buskirk and Tipton[47] for those interested in a detailed look at the development of exercise physiology in the US.

IN SUMMARY

- The increase in research in exercise physiology was a catalyst that propelled the transformation of physical education departments into exercise science and human movement departments. The number of exercise physiology laboratories increased dramatically between the 1950s and 1970s, with many dealing with problems in systemic and applied physiology and the biochemistry of exercise.
- In the future, the emphasis will be on molecular biology and its developing technologies as the essential ingredients needed to solve basic science issues related to physical activity and health.
- However, there is no question about the need for additional research to better understand how to permanently change the physical activity and eating behaviours of individuals in order to realise health-related goals.

A LOOK BACK—IMPORTANT PEOPLE IN SCIENCE

Thomas K. Cureton, Jr., Ph.D.

Dr. Thomas K. Cureton, Jr., was born in Florida in 1901. He studied electrical engineering for two years at Georgia Tech and completed his undergraduate degree in that area at Yale University in 1925. During his childhood and throughout his college career he was very interested in sports, becoming a champion runner and swimmer along the way. This stimulated his interest in exercise and training and he completed elective coursework in anatomy, physiology and biology at Yale as a part of his undergraduate degree. After graduation and while working full time, he completed coursework for a B.S. in physical education in 1929 at Springfield College, one of the best-known schools for training in that area. He was appointed as an instructor in mathematics and chemistry at that college and eventually became director of its Biophysics, Anthropometry and Kinesiology Laboratory. Over the course of the next 10 years, he completed his M.S. (Springfield College) and Ph.D. (Columbia University) degrees.[48]

The focus of Dr. Cureton's research was on physical fitness. In 1941 he was hired by the University of Illinois and three years later he opened the Physical Fitness Research Laboratory, one of the few laboratories in the world dedicated to studying the impact of exercise on fitness and health. The laboratory developed and validated fitness tests, established norms for those tests, developed methods to prescribe exercise to improve fitness and provided opportunities for graduate students to do research projects[49, 50] (pp. 177–83).

Dr. Cureton was an incredibly productive writer and speaker, not just for science-related publications and conferences, but also for public consumption, especially through the YMCA. He was a strong voice for using physical activity to help patients recover from various medical problems. Given the fact that this was a time when physicians were recommending bed rest, it is no surprise that he had an uphill battle. However, Dr. Cureton made his point by showing, through his research, the importance of having patients become physically active in order to return to a productive life. In addition, he was an early advocate of preventing problems in the first place; his 'Run for Your Life' program at the University of Illinois was put in place long before jogging became a popular activity. He became a well-known public figure appearing on TV, was interviewed by numerous papers and became a focus of a special Time-Life book, *The Healthy Life: How Diet and Exercise Affect Your Heart and Vigour*.[51] If you were to read that book today, within the context of our current epidemics of obesity and physical inactivity, you would realise how far ahead Dr. Cureton was in the promotion of physical activity and fitness.

As mentioned earlier, one of the primary purposes of Dr. Cureton's Physical Fitness Research Laboratory was to provide opportunities for graduate students to become trained in doing research on physical fitness. The proceedings from a symposium honouring Dr. Cureton in 1969 listed sixty-eight Ph.D. students who completed their work under his direction.[52] Although Dr. Cureton's scholarly record includes hundreds of research articles and dozens of books dealing with physical fitness, the publications of his students in the areas of epidemiology, fitness, cardiac rehabilitation and exercise physiology represent the 'multiplying effect' that students have on a scholar's productivity. For those who would like to read more about Dr. Cureton, see Berryman's article.[53]

TABLE I.2 **Significant Exercise Physiology Subject Matter Areas That Were Investigated between 1954 and 1994**

A. Basic Exercise Physiology
Exercise Specificity
Exercise Prescription
Central and Peripheral Responses and Adaptations
Responses of Diseased Populations
Action of Transmitters
Regulation of Receptors
Cardiovascular and Metabolic Feed Forward and Feedback Mechanisms
Substrate Utilisation Profiles
Matching Mechanisms for Oxygen Delivery and Demand
Mechanisms of Signal Transduction
Intracellular Lactate Mechanisms
Plasticity of Muscle Fibres
Motor Functions of the Spinal Cord
Hormonal Responses
The Hypoxemia of Severe Exercise
Cellular and Molecular Adaptive Responses

B. Applied Exercise Physiology
Performance of Elite Athletes
Performance and Heat Stress
Exercise at Altitude
Nutritional Aspects of Exercise
Fluid Balance During Exercise
Performance and Ergogenic Aids
Training for Physical Fitness

From: C. M. Tipton, Contemporary exercise physiology: Fifty years after the closure of Harvard Fatigue Laboratory. In *Exercise and Sport Sciences Reviews*, vol. 26, pp. 315–39, 1998. Edited by J. O. Holloszy. Baltimore: Williams & Wilkins.

PROFESSIONAL AND SCIENTIFIC SOCIETIES AND RESEARCH JOURNALS

The expansion of interest in exercise physiology and its application to fitness and rehabilitation resulted in an increase in the number of professional societies in which scientists and clinicians could present their work. Prior to 1950, the two major societies concerned with physiology of exercise and its application were the American Physiological Society (APS) and the American Association of Health, Physical Education and Recreation (AAHPER). The need to bring together physicians, physical educators and physiologists interested in physical activity and health into one professional society resulted in the founding of the American College of Sports Medicine (ACSM) in 1954 (see Berryman's history of the ACSM in the Suggested Readings), Sports Medicine Australia and Sports Medicine New Zealand in 1963, and, more recently, Exercise and Sport Science Australia in 1991, and Sport and Exercise Science New Zealand in 1993.

The explosion in exercise physiology research over the past 60 years has been accompanied by a dramatic increase in the number of professional and scientific societies and research journals communicating research findings. Table I.3 provides a list of some of the main research journals that publish research in exercise physiology.

Training in Research

One of the clear consequences of this increase in research activity is the degree to which scientists must specialise to compete for research grants and to manage the research literature. Laboratories may focus on neuromuscular physiology, cardiac rehabilitation or the influence of exercise on bone structure.

This specialisation in research has generated comments about the need to emphasise 'basic' research examining the mechanisms underlying a physiological issue rather than 'applied' research, which might describe responses of persons to exercise, environmental or nutritional factors. It would appear that both types of research are needed and, to some extent, such a separation is arbitrary. For example, one scientist might study the interaction of exercise intensity and diet on muscle hypertrophy, another may characterise the changes in muscle cell size and contractile protein, a third might study changes in the energetics of muscle contraction relative to cytoplasmic enzyme activities and a fourth might study the gene

TABLE I.3 **Sample of Research Journals for Exercise Physiology Research**

Acta Physiologica (Scandinavia)
Adapted Physical Activity Quarterly
American Journal of Physiology
Aviation, Space and Environmental Medicine
Applied Physiology, Nutrition, and Metabolism
European Journal of Applied Physiology
European Journal of Sport Science
Exercise and Sport Sciences Reviews
International Journal of Sports Medicine
International Journal of Sport Nutrition
International Journal of Sports Physiology and Performance
Journal of Aging and Physical Activity
Journal of Applied Physiology
Journal of Cardiopulmonary Rehabilitation
Journal of Clinical Investigation
Journal of Nutrition
Journal of Physical Activity and Health
Journal of Physiology
Journal of Science and Medicine in Sport
Journal of Sport Science
Journal of Strength and Conditioning Research
Medicine and Science in Sports and Exercise
Pediatric Exercise Physiology
Research Quarterly for Exercise and Sport
Sports Medicine

expression needed to synthesise that contractile protein. Where does 'applied' research begin and 'basic' research end? In the introduction to his text *Human Circulation*,[54] Loring Rowell provided a quote from T. H. Huxley that bears on this issue:

> I often wish that this phrase 'applied science' had never been invented. For it suggests that there is a sort of scientific knowledge of direct practical use, which can be studied apart from another sort of scientific knowledge, which is of no practical utility and which is termed 'pure science.' But there is no more complete fallacy than this. What people call applied science is nothing but the application of pure science to particular classes of problems. It consists of deductions from those principles, established by reasoning and observation, which constitute pure science. No one can safely make these deductions until he has a firm grasp of the principles; and he can obtain that grasp only by personal experience of the operations of observation and of reasoning on which they are found.[55]

Solutions to chronic disease problems related to physical inactivity (e.g. type 2 diabetes mellitus, obesity) will come from a range of scientific disciplines—from epidemiologists on the one hand[56] to cell biologists on the other.[57] We hope that all forms of enquiry are supported by fellow scientists so that present theories related to exercise physiology are continually questioned and modified. Last, we completely agree with the sentiments expressed in a statement ascribed to Arthur B. Otis: 'Physiology is a good way to make a living and still have fun'.[58]

IN SUMMARY

- The growth and development of exercise physiology over the past 60 years has resulted in dramatic increases in the number of organisations and research journals. These journals and professional meetings provide additional opportunities for research findings to be disseminated.
- A greater need exists for university graduates to identify and specialise in a particular area of research in their careers in order to find the best mentor and university program to realise career goals.

CAREERS IN EXERCISE SCIENCE, SPORT SCIENCE OR EXERCISE PHYSIOLOGY

Over the past 30 years there has been a sustained growth in career opportunities for those with academic training in exercise science. Currently, students pursue careers as exercise scientists and accredited exercise physiologists in private, commercial, work-site, and hospital settings; strength and conditioning in commercial, rehabilitative and sport-related environments; and the traditional allied health professions (e.g. physiotherapy, occupational therapy) and medicine (e.g. physician assistant, sports physician). For those interested in a career as an accredited exercise physiologist, coursework is not enough—students must develop the requisite skills needed to perform the job. That means that students should be completing practicum and internship experiences under the direction of a professional who can pass along what cannot be taught in a classroom or laboratory. Students should make contact with their advisors early in the program to maximise what can be gained from these experiences. Interested students should read the article by Pierce and Nagle on the internship experience.[59] However, more may be needed to realise your career goal.

In Australia, those who are interested in working with individuals with chronic diseases or conditions should undertake accreditation as an exercise physiologist (AEP) through the Exercise and Sport Science Australia pathway. AEPs are university-qualified allied health professionals who specialise in the delivery of exercise, lifestyle and behavioural modification programs for the prevention and management of chronic diseases and conditions. To attain accreditation as an AEP, a student must complete study at a university that has ESSA-approved National University Course Accreditation Program certification. This ensures that the student will gain sufficient theoretical and practical experience to work as an allied health professional in this field.

Over the past few years a special initiative, Exercise is Medicine™ (http://exerciseismedicine.org.au) was developed by the American College of Sports Medicine and the American Medical Association and expanded into Australia to encourage those working in the medical and the allied health professions to routinely promote physical activity to their patients. In addition to that goal, these health professionals need to know where to refer patients when they need more formal support for their physical activity program. For example, physiotherapists need to know where to direct their patients after initial treatment has been completed. This emphasises the need for good communication between the allied health and fitness professionals. This text provides the essential information to help all of you be more effective in that regard.

Last, but not least, if you are interested in pursuing a career in research so that you can teach and complete research at a university or other research institution, you should become involved in research while you are an undergraduate. You might volunteer as a participant for another student's research project, take course credit to assist your lecturer in his or her research or use a summer break to work in a researcher's lab at another institution. If a particular area of research interests you, perform a PubMed search (www.ncbi.nlm.nih.gov/pubmed) to see who is currently active in the area, which will help you narrow down potential postgraduate programs. Go online and determine what the requirements are for admission to the postgraduate programs you are interested in; this will give you time to take appropriate coursework to meet those requirements.

IN SUMMARY

- A variety of career paths exist for undergraduates majoring in exercise and sport science. Get some practical experience while you are an undergraduate to help you make a decision about your future, and facilitate entry to a profession or postgraduate school.
- Organisations such as Exercise and Sport Science Australia, Sports Medicine Australia, the Australian Strength and Conditioning Association and Sport and Exercise Science New Zealand have developed certification programs to establish a standard of knowledge and skill to be achieved by those who lead and assist with exercise programs.

STUDY QUESTIONS

1. Identify two of the most prolific scientists in your personal area of interest in exercise physiology and briefly describe what they have done. Use a research database at the library to find your references.
2. Pick a topic of interest in exercise physiology and describe how a molecular biologist might approach it compared to a scientist interested in doing studies with humans.
3. Identify one potential career that you are interested in and find out the current expectations for growth in that profession, what a typical salary is and what additional degrees (if any) are needed to realise your goal.
4. Identify the primary scientific meeting your lecturers attend. Find out if the organisation that sponsors that meeting has a membership category for students, how much it costs and what you would receive (e.g. journals) if you joined.

SUGGESTED READINGS

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